

APPENDIX 1: DEMONSTRATOR VEHICLE ELEMENT REQUIREMENTS

1. SCOPE

This appendix provides the performance and design requirements for the Demonstrator Vehicle (DV). The DV includes airframe, vehicle management, propulsion, power, communication, and instrumentation subsystems.

2. REQUIREMENTS

2.1. GENERAL SYSTEM REQUIREMENTS

2.1.1. The DV shall be capable of accelerating from Mach 5 to Mach 7 during the Engine Test Phase.

2.1.2. The DV shall be capable of stable, autonomously-controlled flight from Separation through the Descent Phases of the mission, both powered and un-powered. Government-defined operation scenarios and mission(s) definition are provided for reference in the Operations Concept Document (OCD), X43C Document 0102-02.

2.1.3. The DV shall be capable of providing data required to monitor the operational readiness of the DV and its subsystems, including data to monitor internal environment and safety-related functions, during all mission phases.

2.1.4. The DV parameters, as shown in Addendum A, X-43C Research Measurements List, shall be reported to GSE/GTE, DV Monitoring Station (DVMS) in the CAC, and EWR facilities as applicable to the specific mission phase.

2.1.5. All telemetry shall be compatible with EWR and RTO facilities required for the flight tests. Telemetry formats shall adhere to IRIG 106-01. The telemetry transmission shall conform to applicable sections of IRIG Standard 106-01. All telemetered data shall be time tagged from a common time reference.

2.1.6. The DV shall contain a DV flight termination subsystem in accordance with the Eastern and Western Test Range regulation EWR 127-1.

2.1.7. The DV shall have positive design margin through the completion of the Engine Test Phase.

2.1.8. The Contractor shall evaluate design margin through the completion of the Descent Phase.

2.1.9. The DV design shall be fail-safe during mission phases where hazards to human life exist.

2.1.10. The DV and interfaces to the CAC/GSE/GTE shall be designed to allow the redundant controlled venting of any hazardous materials contained within the DV when

commanded during Pre-flight, Captive Carry, RTB, and Post-flight mission phases.

2.1.11. The DV shall have the capability of fully discharging any remaining residual subsystem pressures at water impact.

2.1.12. The DV design shall provide for all internal cavities that could have combustible-mixture contamination to be purged, vented, and monitored for leakage through Engine Test Phase or RTB. The design shall allow purge during Ground Operations, whether or not mated to the Adapter and/or CAC.

2.1.13. The DV control system shall not alter the mission due to detection of a combustible mixture after Drop/Boost is initiated.

2.1.14. The DV shall be designed to provide neutral to positive static stability.

2.1.15. The DV mass properties and their accuracies shall be a derived requirement based upon the CAC capability, Booster capability, and ability of the DV to perform mission requirements. The mass properties include weight, center of gravity, products and moments of inertia, and liquid fuel slosh frequency. CAC and Booster capability limits will be specified by the Booster/Launch Services Contractor in the Adapter-to-Booster Interface Control Document (ICD).

2.1.16. The DV shall be designed to provide access for external servicing of the fuel, Start Assist Subsystem (SAS), and inert gas tanks while stand-alone or mated to the Adapter and CAC.

2.1.17. The DV shall be designed to provide access for testing through airframe-mounted external connectors and/or hatches, whether or not mated to the Adapter for the following functions:

- GSE to DV interfaces for ground test and commanding
- External monitoring of the DV RF signals
- Sensor signal outputs and Pulse Code Modulation (PCM) stream(s)
- Simulated signal inputs to the Instrumentation Subsystem and evaluation of the installed sensor output signals
- Software uploads

2.1.18. All required test connections shall be accessible without removal of adjacent components, other subsystems, or major structural components.

2.1.19. The DV shall provide internal and external reference markings for the vehicle coordinate system definition. Reference markings shall enable establishment of pitch and roll reference planes.

2.1.20. The DV shall have reference points for rigging of control surface and sensor location for all three axes that allow the measurement of control surface position (externally).

2.1.21. The Contractor shall perform Thermal Protection System (TPS) maintenance and repairs, as required, at the RTO.

2.1.22. Pressure vessels shall be designed to the burst factor of 2.5 as opposed to the value specified in MIL-STD-1522A section 5.1.3 and 5.2.3. Other components shall conform to MIL-STD-1522A section 5.3.

2.1.23. The Contractor shall provide an assembly fixture/transportation cart for the DV. The assembly fixture/transportation cart shall be adjustable to facilitate testing and integration of the DV with the Adapter. The assembly fixture/transportation cart shall be functional with or without engine attached to the DV and shall facilitate engine installation/removal.

2.1.24. The Contractor is responsible for building in handling capability within the integrated DV/Adapter assembly or associated handling carts to permit Booster integration and test (e.g. fixture/article clearance allowances for mating, electrical and mechanical connections, functional test accessibility, etc.)

2.1.25. The DV shall have lifting points used to facilitate assembly, transportation, and verification.

2.1.26. The DV shall have a minimum of three (3) hard points on each upper and lower surface to facilitate storage and handling. The points shall be centered about the CG of the DV for stability.

2.2. AIRFRAME

2.2.1. Performance

2.2.1.1. The DV structure shall provide the strength and stiffness to maintain proper vehicle function with positive design margin during ground operations and from Captive Carry through Engine Test Phases.

2.2.1.2. The DV design shall prevent engine exhaust plume interaction on the control surfaces.

2.2.1.3. The DV structure shall be free of any dynamic aeroelastic or aeroservoelastic instability through the Engine Test Phase.

2.2.1.4. The DV structure, when mated with the Adapter, shall be designed to a derived requirement based upon achieving a fundamental structural first bending mode frequency for the assembled LV of 7.5 Hz actual and 8.8 Hz predicted. The Government will provide a finite element model of the Booster (X43C-GF010, X43C Booster Finite Element Model) to facilitate Contractor derivation of the requirement.

2.2.1.5. The DV structural deflections shall not compromise scramjet performance or induce forebody or ramp-shock impingement on the cowl leading edge when loaded at the designed powered flight conditions.

2.2.1.6. The forebody boundary layer flow entering the engine flowpath shall be turbulent.

2.2.2. Design

2.2.2.1. The DV OML shall conform to X43C-GFI-001, DV/Adapter OML Definition.

2.2.2.2. The DV propulsion flowpath materials, including the forebody TPS, shall be non-ablative.

2.2.2.3. The DV shall be designed to withstand three-sigma Monte Carlo mechanical and thermal loads for all mission phases through Engine Test Phase.

2.2.2.4. All primary structure shall be designed to ensure positive design margin with the following minimum factors of safety applied for the corresponding phase of the mission.

Phase	Factors of Safety			
	Yield	Ultimate	Composites	Thermal - yield
Ground Test	2.25	2.5	3.0	1.5
Pre-Flight	2.25	2.5	3.0	1.5
Captive Carry	2.25	2.5	3.0	1.5
RTB	2.25	2.5	3.0	1.5
Drop/Boost	1.1	1.5	2.0	1.0
Separation	1.1	1.5	2.0	1.0
Coast	1.1	1.5	2.0	1.0
Engine Test	1.1	1.5	2.0	1.0
Descent	0	0	0.0	0.0

2.2.2.5. All primary structure shall be designed to ensure positive design margin with the following load factors applied for the corresponding phase of the mission.

Phase	Load Factors		
	Heat Rates	Pressures	Inertial
Ground Test	1.0	1.0	1.0
Pre-Flight	1.0	1.0	1.0
Captive Carry	1.0	1.0	1.0
RTB	1.0	1.0	1.0
Drop/Boost	1.2	1.0	1.0
Separation	1.2	1.0	1.0
Coast	1.2	1.0	1.0
Engine Test	1.2	1.0	1.0
Descent	0	0	0.0

2.2.2.6. Additional factors of safety shall be applied per aerospace industry standards including but not limited to those that are normally applied to fittings, castings, fasteners, fluid and gaseous plumbing, and billet-size.

2.2.2.7. The Contractor shall design the DV to meet the life requirements outlined in the table below at the end of Engine Test Phase.

Life Function	Requirements
Low-cycle fatigue	2% strain/10 cycles
High-cycle fatigue	1,000,000 cycles
Fluid systems service life	100 mission-duty cycles

2.3. VEHICLE MANAGEMENT SUBSYSTEM (VMS)

2.3.1. The DV shall have a VMS that provides mission and flight management functions, including but not limited to flight control, guidance, navigation, and subsystem management. The flight control computer, including guidance and navigation function, is referred to as the Flight Management Unit (FMU).

2.3.2. The VMS shall provide DV guidance, navigation, and control for all mission phases from Separation through Descent.

2.3.3. The navigation system shall calculate all DV state information in both vehicle reference coordinate system and geodetic coordinate system.

2.3.4. The navigation system shall provide information for flight guidance and control functions with a minimum update rate of 100 Hertz and maximum latency of 10ms and conform to minimum 3-sigma accuracies as specified in the table below.

States	Accuracy
Position	60 ft
Relative velocity	15 ft/s (axial), 2 ft/s (lateral)
Flight path & heading angles	0.2 deg
Mach number	0.05
Dynamic pressure	20 psf
Angle of attack & sideslip	0.2 deg
Attitude	0.2 deg
Angular rate	0.05 deg/sec
Acceleration	0.001g

2.3.5. All structural modes shall be filtered with at least 9 dB of gain margin to prevent

flight control and structure interaction.

2.3.6. The control function shall ensure that the DV remains within an accuracy as defined in the table below about the DV reference trajectory within 3-sigma Monte Carlo.

Flight Phase	Accuracy			
Recovery after Separation	Mach	Qbar(psf)	α (deg)	β (deg)
	+/- 0.25	+/- 100	+/- 1.5	+/- 1.5
Engine Test	Mach	Qbar(psf)	α (deg)	β (deg)
	+/- 0.1	+/- 50	+/-0.5	+/-0.5
Descent	Mach	Altitude(ft)	α (deg)	β (deg)
	+/- 0.1	+/- 500	+/-0.5	+/-0.5

2.3.7. DV stabilization and tracking about the reference trajectory shall be maintained in the presence of, at a minimum, the following disturbances:

- Separation
- Aerodynamic uncertainties
- Atmospheric uncertainties
- Cowl opening/closing
- Ignition
- Engine operation
- CG shifts
- Fuel slosh

2.3.8. The control system design shall meet allowable RMS deviations based on the turbulence model.

2.3.9. The VMS shall support communications with GSE/GTE (including the Vehicle System Demonstrator (VSD)) via the DV GSE interface.

2.3.10. The VMS shall support an engine-off state for software and control hardware maintenance/testing.

2.3.11. The flight control function shall conform to the following:

- All loop closures must have 6dB gain margins and 45-degree phase margins.
- All closed loop damping ratios shall be greater than 0.3.

- Any sustained control system residual oscillations shall not interfere with mission flight phase performance requirements.
- Any residual oscillations in pitch, yaw, and roll attitudes shall not exceed 0.2 deg peak.
- The steady state accuracies for pitch, yaw, and heading angles shall be within ± 0.5 deg, roll angle ± 1.0 deg.
- The dynamic response transients shall be smooth and rapid with one overshoot of less than 20% before settling. Equivalently, the response bandwidth and overshoot shall be such that is shall not compromise mission performance.

2.4. POWER DISTRIBUTION SUBSYSTEM (PDS)

2.4.1. Performance

2.4.1.1. The DV shall be capable of providing power for all internal subsystems and functions from an onboard PDS for the duration of the mission beginning 5 minutes prior to Drop/Boost and extending through the Engine Test Phase.

2.4.1.2. The power available for high-load subsystems (e.g., pumps, actuators, etc.) shall be at least 25% greater than the power required to complete the Engine Test Phase.

2.4.1.3. The power available for low-load subsystems (e.g., instrumentation, controls, etc.) shall be at least 100% greater than the power required to complete the Engine Test Phase.

2.4.1.4. The DV shall be capable of operating by means of its on-board PDS, a ground power source (with or without Booster), and power supplied by the CAC when the LV is attached.

2.4.1.5. Power-source transitioning shall not produce voltage or current transients that disturb normal operation of DV subsystems.

2.4.2. Design

2.4.2.1. An externally-activated on-board method of energizing and de-energizing the PDS shall be provided.

2.4.2.2. Protection for DV subsystems and components shall be provided to minimize impacts due to failure of other individual subsystem(s).

2.4.2.3. Protection against damage shall be provided for DV subsystems when an external power source (GSE or CAC) is applied.

2.4.2.4. Internal DV and Adapter subsystems and structural components shall be grounded to a common airframe ground.

2.4.2.5. An externally-accessible, single-point electrical ground shall be provided on the DV and Adapter.

2.4.2.6. Electrical systems shall be designed to meet NFPA 70 (national electric code), article 500 (hazardous locations), class I (flammable gases), group B (hydrogen), division 2 (potentially flammable condition). Electrical systems shall be qualified to MIL-STD-810F (environmental testing), method 511.3 (explosive atmosphere), procedure I (non-ignition of flammable atmosphere), to altitudes up to 120,000 ft., using JP-7 fuel.

2.5. COMMUNICATIONS

2.5.1. Performance

2.5.1.1. The communication subsystem shall telemeter the measurements for health monitoring, flight performance, and per Addendum A, Research Measurements List, to EWR facilities.

2.5.1.2. The communication subsystem shall provide for active radar tracking of the DV compatible with EWR facilities.

2.5.1.3. The radar system RF antenna pattern shall provide no less than 95% spherical coverage from Drop/Boost through Descent Phases.

2.5.1.4. The Contractor shall provide a communication and radar link analysis and perform an antenna radiation pattern test to verify link performance throughout the mission.

2.5.1.5. The antenna radiation pattern test shall be performed on an externally-completed airframe flight configuration.

2.5.2. Design

2.5.2.1. The telemetry transmission shall conform to applicable sections of IRIG Standard 106-01.

2.5.2.2. The communication subsystem shall include a means to externally enable/disable the transmitter(s) RF outputs from either GSE or the CAC without disabling other components within the DV.

2.5.2.3. The telemetry transmitter(s) center frequency shall be in-field selectable across the assigned frequency band that is compatible with EWR.

2.6. INSTRUMENTATION

2.6.1. Performance

2.6.1.1. The instrumentation subsystem shall acquire measurements as per Addendum A, X-43C Research Measurements List.

2.6.1.2. The instrumentation subsystem shall condition (sensor excitation, input voltage range, cold-junction compensation, filtering) and acquire analog data from sensors as required to satisfy Addendum A, X-43C Research Measurements List.

2.6.1.3. The instrumentation subsystem shall sample data from the asynchronous digital subsystems (FMU or Engine Control Unit (ECU)) at a rate greater than the update rate of the FMU and ECU to preclude any missing data.

2.6.2. Design

2.6.2.1. Type and location of instrumentation sensors shall be proposed 45 days prior to PDR.

2.6.2.2. The instrumentation subsystem shall provide a means of indicating any repeated data words in the telemetered data stream.

2.6.2.3. The instrumentation subsystem shall provide a PCM output stream to the CAC and GSE/GTE via a hard-wired umbilical.

2.6.2.4. The instrumentation subsystem shall be reprogrammable via GSE interface.

2.6.2.5. The Contractor shall evaluate, characterize, and document sources of instrumentation error to obtain total measurement uncertainty for each parameter.

2.6.2.6. A system-level calibration of all input signals shall be performed to obtain the coefficients required to calculate the measured value, in engineering units, of each parameter from the PCM analog-to-digital counts.

2.7. DESIGN AND CONSTRUCTION

2.7.1. Tolerances

2.7.1.1. The DV OML including the engine cowl and sidewall external surfaces (excluding the Propulsion Flowpath) and the DV/Adapter interface shall be maintained within the following manufacturing tolerances (unloaded):

- The maximum butt gap and surface mismatch gap shall not exceed 0.030 inches.
- Maximum exterior contour deviations shall not exceed 0.060 inches.
- Surface waviness shall not exceed 0.030 inches from peak-to-valley in a 6-in span.
- The exterior surface roughness shall not exceed 64 micro-inches rms for metal surfaces and 128 micro-inches rms for the TPS.

2.7.1.2. Forward and aft facing steps shall not exceed 0.040 and 0.060 inches (respectively) at any location on the DV OML including the engine cowl and sidewall external surfaces (excluding the Propulsion Flowpath) from Drop/Boost through Engine Test Phase.

2.7.1.3. Airframe surfaces contained within the propulsion flowpath, including but not limited to the forebody, shall meet the tolerance requirements as specified in Appendix 2, Propulsion Subsystem Requirement.